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# STUDY OF TRIBOLOGICAL BEHAVIOR OF FERROUS AND NON FERROUS METALS BY USING PIN ON DISC APPARATUS

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***ABSTRACT***

***The wear and coefficient of friction plays a vital role in designing of gears and bushes. In the present paper experimental investigation is carried out on pairs of materials like Brass-Steel, Al-Steel and Steel-Steel to obtain coefficient friction and wear using a pin-on-disc apparatus. Experiments are performed on the flat circular disk and circular pin and these are perpendicular to each other. The present study focusing on a parametric study of the frictional coefficient and wear by varying speed, wear track diameter, contact pressure and temperature as design variables. Also, develop a regression equation by using Data Fit software. The results are also compared with disk and pin contact temperature with respect to the coefficient of friction.***

***KEYWORDS:** Steel, Aluminum, Brass, Wear Rate, Coefficient of Friction & Regression Equation*

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Original Article

## INTRODUCTION

Tribology simply means the relation between surfaces interacting in relative motion. Generally, tribology is full meaning the rubbing of the materials. Tribological behavior is divided into three types basing on the friction, wear and lubrication. Currently, different ferrous and non-ferrous metal combinations are widely used for tribological applications. Ferrous and non-ferrous metals are used for bearing, Gear and gear pin materials to achieve a high wear resistance. Due to this tribological application, different combinations of materials have been selected for the research. For instance, a worm and worm wheel is designed with steel and brass respectively. Different metal combinations have been selected for this study. The experiment investigates the study that has been conducted by various researchers. It was observed that friction and wear depended on several parameters. Parameters which affect the wear rates and friction rate such as normal load, surface roughness, and sliding velocity are considered.

The present study is focusing on two parameters which are normal load and sliding velocity. These two are the parameters which outline results in tribological behavior performance of metals. All experiments are carried as per ASTM G- 99 standards using pin-on-disc apparatus to obtain the coefficient of friction and wear test. The experiments are carried with 3 mm diameter pin (steel, Aluminium & Brass) materials and 165mm diameter

steel material disc.

Siddhartha et al. [1] studied the fabrication of aluminum/boron carbide metal matrix composite and investigation on its tribological behavior. The Wear parameter was conducted on pin-on-disc tester based on Taguchi's L27 orthogonal array using three process different parameters such as applied load, sliding velocity, and track distance. It was observed that the coefficient of friction increase with load and decreasing the rubbing velocity with track distance. Himanshu et.al [2] studied about the mechanical and tribological properties of stir cast aluminum matrix composites containing single and multiple reinforcements. Addition of alumina to aluminum has shown an increase in its mechanical and tribological properties. Improved the tensile and yield strength by using Organic reinforcement like fly ash, coconut ash, and aluminum along with the tribological behavior of the composite. An improved form of the above is fabricated as well.

M. A. Chowdhuury et.al [3] studied and fabricated friction coefficients of different material pairs. Investigated and compared those. The results suggest that the coefficient of friction varies due to reasons like rubbing, normal load and sliding velocity. Material pairs show that friction coefficient decreases with the increase in normal load for brass and copper. When tested with different materials pairs, it turns out to be same. The results are found that friction coefficient decreases with the increase in normal load. It was observed that values of the friction coefficient increase with an increase in sliding velocity.

Nuruzzaman et.al [4] study is on steel pins and disk materials for which he took brass, aluminum and copper materials pairs. The steel pin is subjected to different normal load conditions. The results shows the when the load is increasing, the sliding velocities and wear rate also increases. From the results, it is found that the wear rate of aluminum and brass is lower than copper. Kiran Deore et.al [6] compared the wear rate of Stainless Steel 316, Stainless Steel 304, Stainless Steel 410, Copper, Brass and Aluminum. The results show that the steel wear rate is higher than the remaining materials. The brass wear rate is a smooth curve shape in the graph. Vishnu Priya et.al [7] investigated the wear behavior of Al-Ni-SiC metal matrix composites content within the 8011 Al alloy. The results obtaining by decreasing the aluminum alloy 8011 compared to the metal matrix composite materials.

S. Srivastava et.al. [8] Investigated the electrolytic powder of 300mesh size particles different places (randomly) in the melt of pure aluminum. The results obtained by the microstructure in material boundary conditions and material structure. The electrolytic grain size powder particles are observed under the electron probe microanalyzer (EPMA) and x-ray diffraction (XRD). The XRD has mainly used the wear debris. Ashok Kr et al. [8] study was on the tribological behavior of aluminum alloy Al-6061 reinforced with silicon carbide particles (10% & 15%) fabricated by stir casting process. The parameters were conducted based on the plan of experiments generated through Taguchi technique. An L9 Orthogonal array was selected for analysis of the data. Confirmation of the final results found something interesting. The results hinted towards making a comparison between experimental values showing an error value is with dry sliding wear & coefficient of friction in both composites. The composites vary from 4 to 11% and 3 % to 9% respectively.

## EXPERIMENTAL SETUP

The pin on disc machine is set up which is shown in Figure 1. Pin is fixed and disk rotates. A steel pin is fitted in a holder and it is fixed to the arm. The pin is flat so that it can be easily slid on the rotating test disc. The arm is working principle is the pivot mechanism. This mechanism can rotate horizontally and vertically with negligible friction. The frictional force is measured for different normal loads using a load cell. To obtain the friction coefficient, the frictional

force is measured for different normal loads. Data acquisition system is store the data of load and wear during experimentation. Table 1 shows the technical specifications of the pin on disc. Figure 2 shows the line diagram of pin on disc apparatus. Figure 3 shows the image of controller. it displays the wear, temperature, coefficient friction and machine speed. Thermocouple a useful measuring temperature sensor for pin and disc. Thermocouple is divided into different types of materials known as types K, J, E and T. In this experiment "K" type thermocouple is used. K type thermocouple useful to measure the contact temperature between the pin and disc. Figure 4 shows the contact temperature between pin on disc.

**Figure 1**: **Image of Pin on Disk Apparats**

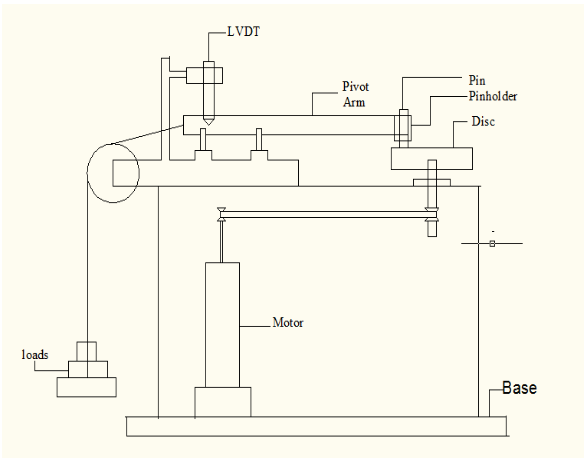


**Figure 2**: **Line Diagram of Pin on Disc Apparats**

**Table 1**: **Technical Specifications of Pin on Disc**

| S. No. | Test Parameter | Values |
|---|---|---|
| 1 | Specimen size | Pin size 3 to 12mm, Pin dia 32mm long |
| 2 | Normal loads | 5 to200N |
| 3 | Disc size | 165mm |
| 4 | Disc Thickness | 8mm |
| 5 | Rotational Speed | 200rpm To 2000 rpm |
| 6 | Wear track diameter | 5mm to 160mm |
| 7 | Wear rate | 0µm to 2000µm |
| 8 | Thermocouple | K-type thermocouple |
| 9 | Temperature | 0 to500°c |
| 10 | Lubrication Module | with re- circulation system |
| 11 | Loading system | Using dead weights. |

**Figure 3**: **Controller**

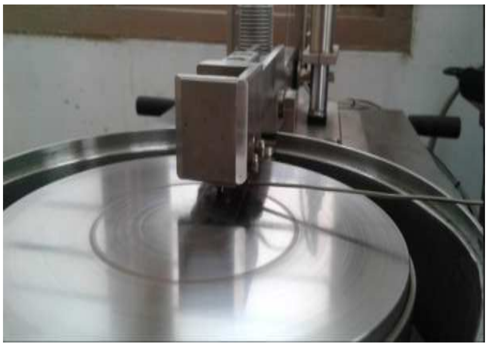

**Figure 4**: **K-Type Thermocuple**

## EXPERIMENTAL INVESTIGATION

The pin on disc machine is used for evaluating the wear and coefficient of friction under the dry sliding test condition and temperature conditions. The dry sliding test performed by three conditions at load, speed and track diameter. The experiments are carried at const load and varying rubbing velocity.

### Experimental Conditions

Test conditions are apply the different loads at a constant speed and wear track diameter. Another condition is at constant load and wear track diameter and varying the speed.

### Steel pin

The experiments are carried out at a constant speed by varying load on 3mm diameter of steel pin against the steel disk, Speed and Track diameter. Table 2 shows the Test conditions for Steel pin on steel disk at a constant speed. Table 3 shows the test conditions for Steel pin on steel disk at constant load. These experiments are carried out at constant load and varying the track diameter and speed on 3mm diameter of steel pin against steel disk.

**Table 2: Test Conditions for Steel Pin on Steel Disk at a Constant Speed**

| S. No | Load (N) | Speed (RPM) | Track Diameter (mm) |
|---|---|---|---|
| 1 | 30 | 500 | 60 |
| 2 | 60 | 500 | 60 |
| 3 | 90 | 500 | 60 |

**Table 3**: **Test Conditions for Steel Pin on Steel Disk at a Constant Load**

| S. No | Load (N) | Speed (RPM) | Track Diameter (mm) |
|---|---|---|---|
| 1 | 40 | 400 | 60 |
| 2 | 40 | 600 | 60 |
| 3 | 40 | 800 | 60 |

**Aluminum Pin**

The experiments are carried out at a constant speed by varying load on 3mm diameter of the aluminum pin against the steel disk, Speed and Track diameter. Table 4 shows the Test conditions for the aluminum pin on steel disk. Table 5 shows the test conditions for the aluminum pin on steel disk. These experiments are carried out at constant load and varying the track diameter and speed on 3mm diameter of the aluminum pin against steel disk.

**Table 4**: **Test Conditions for Aluminum Pin on Steel Disk at Constant Speed**

| S. No | Load (N) | Speed (RPM) | Track Diameter (mm) |
|---|---|---|---|
| 1 | 5 | 400 | 40 |
| 2 | 10 | 400 | 40 |
| 3 | 15 | 400 | 40 |

**Table 5**: **Test Conditions for Aluminum Pin on Steel Disk at Constant Load**

| S. No | Load (N) | Speed (RPM) | Track Diameter (mm) |
|---|---|---|---|
| 1 | 10 | 300 | 40 |
| 2 | 10 | 400 | 40 |
| 3 | 10 | 500 | 40 |

**Brass Pin**

The experiments are carried out at a constant speed by varying load on 3mm diameter of brass pin against the steel disk, Speed and Track diameter. Table 6 shows the test conditions for a brass pin on steel disk. Table 7 shows the test conditions for the brass pin on steel disk. These experiments are carried out at constant load and varying the track diameter and speed on 3mm diameter of the brass pin against steel disk.

**Table 6**: **Test Conditions for the Brass Pin on Steel Disk at a Constant Speed**

| S. No | Load (N) | Speed (RPM) | Track Diameter (mm) |
|---|---|---|---|
| 1 | 5 | 400 | 40 |
| 2 | 10 | 400 | 40 |
| 3 | 15 | 400 | 40 |

**Table 7: Test Conditions for Steel Pin on Steel Disk at Constant Load**

| S. No | Load (N) | Speed (RPM) | Track Diameter (mm) |
|---|---|---|---|
| 1 | 10 | 300 | 40 |
| 2 | 10 | 400 | 40 |
| 3 | 10 | 500 | 40 |

## RESULTS AND DISCUSSIONS

A coefficient of friction is obtained for 3mm diameter of a steel pin and steel disc at constant contact pressure in the dry sliding test condition. From the Table 8, it is observed that the coefficient of friction is decreases with the increase of load. The increase of contact temperature may be possible reason for decreasing of coefficient of friction. Wear is obtained for 3mm diameter of steel pin and steel disc at constant contact pressure in the dry sliding test condition. From table 8 it observed that the coefficient friction is decreases with increases of rubbing velocity at constant rubbing velocity. From the Table 8 it is also observed coefficient of friction decreases with the increases of contact temperature. From the Table 9, it is observed that, by increasing rubbing velocity wear is also increasing due to the effect of increasing contact temperature. Figure 5 shows the variation of coefficient friction at constant rubbing velocity for steel pin.

**Table 8: Coefficient of Friction Test Values of Steel Pin on Steel Disk at a Constant Speed**

| S. No | Contact Pressure (MPa) | Rubbing Velocity (mm/s) | Contact Temperature ($^{O}$c) | Co-Efficient of Friction (µ) |
|---|---|---|---|---|
| 1 | 4.2441 | 1570.79 | 46.1 | 0.384 |
| 2 | 8.4883 | 1570.79 | 50.1 | 0.351 |
| 3 | 12.7325 | 1570.79 | 87.6 | 0.336 |

**Table 9**: **Wear Test Values of Steel Pin on Steel Disk at a Constant Speed**

| S. No | Contact Pressure (MPa) | Rubbing Velocity (mm/s) | Contact Temperature ($^{O}$c) | Wear (µm) |
|---|---|---|---|---|
| 1 | 4.2441 | 1570.79 | 46.1 | 75 |
| 2 | 8.4883 | 1570.79 | 50.1 | 75 |
| 3 | 12.7325 | 1570.79 | 87.6 | 395 |

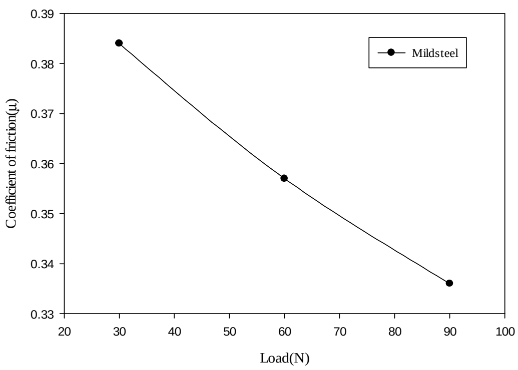


**Figure 5**: **Coefficient of Friction at Constant Rubbing Velocity for Steel Pin**

A coefficient of Friction is obtained for 3mm diameter of Steel Pin and Steel disc at constant contact pressure in dry sliding test condition. From the Table 10 it is observed that the coefficient of friction is decreases with increase of rubbing velocity. The increase of contact temperature may be a possible reason for decreasing of the coefficient of friction. Wear is obtained for 3mm diameter of Steel Pin and Steel disc at constant contact pressure in dry sliding test condition. From the Table 11, it is observed at varying load at constant rubbing velocity wear is decreasing due to the effect of increasing contact temperature. From the Table 10, it is observed at constant normal loads with different rubbing velocities, the coefficient of friction decreases due to the effect of contact temperature increases. From the Table 11, it is also observed wear decreases with the increases of contact temperature. Figure.6 shows the variation coefficient of friction at a constant contact pressure. Figure.6 shows the variation of coefficient friction at constant load for steel pin. Figure.6 shows the coefficient of friction at constant contact pressure for the aluminum pin.

**Table 10**: **Coefficient of Friction Test Values of Steel Pin on Steel Disk at a Constant Contact Pressure**

| S. No | Contact Pressure (MPa) | Rubbing Velocity (mm/s) | Contact Temperature ($^{O}$c) | Co-Efficient of Friction (μ) |
|---|---|---|---|---|
| 1 | 5.6589 | 1256.63 | 55.7 | 0.456 |
| 2 | 5.6589 | 1884.95 | 56.4 | 0.375 |
| 3 | 5.6589 | 2513.27 | 72.4 | 0.372 |

**Table 11**: **Wear Test Values of Steel Pin on Steel Disk at a Constant Contact Pressure**

| S. No | Contact Pressure (MPa) | Rubbing Velocity (mm/sec) | Contact Temperature ($^{O}$c) | Wear (μm) |
|---|---|---|---|---|
| 1 | 5.6589 | 1256.63 | 55.7 | 115.5 |
| 2 | 5.6589 | 1884.95 | 56.4 | 105.3 |
| 3 | 5.6589 | 2513.27 | 72.4 | 102.2 |

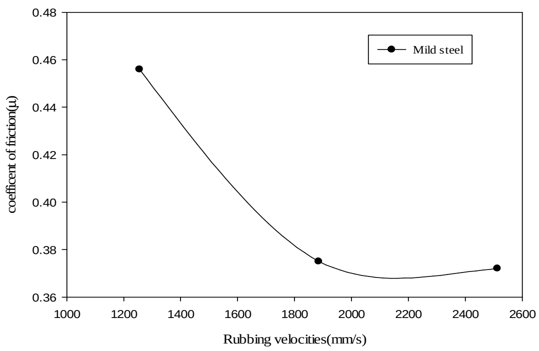


**Figure 6**: **Coefficient of Friction at Constant Contact Pressure for Steel Pin**

Coefficient of friction is obtained for 3mm diameter of aluminum pin and steel disc at constant contact pressure in the dry sliding test condition. From the Table 12, it is observed that coefficient of friction is decreases with increase of load. The increase of contact temperature may be possible reason for decreasing of the coefficient of friction. Wear is obtained for 3mm diameter of the aluminum pin and steel disc at constant contact pressure in dry sliding test condition. From table 12 it observed that the coefficient friction is decreases with increases of rubbing velocity at constant rubbing velocity. From the Table 12 it is also observed the coefficient of friction decreases with the increases of contact

temperature. From the Table 13 various rubbing velocity wear is increasing due to the effect of increasing contact temperature. Figure 7 shows the coefficient of friction at a constant rubbing velocity for aluminum pin.

**Table 12: Coefficient of Friction Test Values of Aluminum Pin on Steel Disk at a Constant Speed**

| S. No | Contact Pressure (MPa) | Rubbing Velocity (mm/s) | Contact Temperature ($^{O}$c) | Co-Efficient of Friction (µ) |
|---|---|---|---|---|
| 1 | 0.704 | 837.75 | 34.2 | 0.596 |
| 2 | 1.414 | 837.75 | 34.9 | 0.430 |
| 3 | 2.122 | 837.75 | 35.9 | 0.277 |

**Table 13: Wear Test Values of Aluminum Pin on Steel Disk at a Constant Rubbing Velocity**

| S. No | Contact Pressure (MPa) | Rubbing Velocity (mm/sec) | Contact Temperature ($^{O}$c) | Wear (µm) |
|---|---|---|---|---|
| 1 | 0.704 | 837.75 | 34.2 | 45 |
| 2 | 1.414 | 837.75 | 34.9 | 8 |
| 3 | 2.122 | 837.75 | 35.9 | 49 |

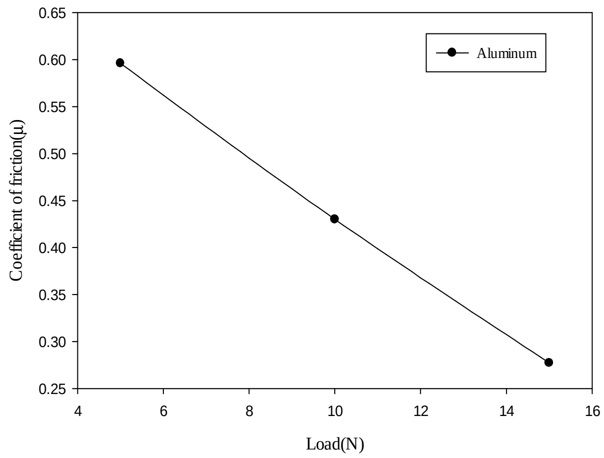


**Figure 7: Coefficient of Friction at Constant Rubbing Velocity for Aluminum Pin**

A coefficient of Friction is obtained for 3mm diameter of aluminum pin and steel disc at constant contact pressure in the dry sliding test condition. From the Table 14, it is observed that the coefficient of friction is decreases with the increase of rubbing velocity. The increase of contact temperature may be possible reason for decreasing of coefficient of friction. Wear is obtained for 3mm diameter of the aluminum Pin and Steel disc at constant contact pressure in the dry sliding test condition. From Table 14, it observed that coefficient friction is decreases with increases of rubbing velocity at constant load. From the Table 15, it is also observed wear decreases with the increases of contact temperature. From the Table 15, various rubbing velocity wear is decreasing due to the effect of increasing contact temperature. Figure 7, shows the coefficient of friction at constant contact pressure for aluminum pin.

**Table 14**: **Coefficient of Friction Test Values of Aluminum Pin on Steel Disk at a Constant Contact Pressure**

| S. No | Contact Pressure (MPa) | Rubbing Velocity (mm/s) | Contact Temperature ($^{O}$c) | Co-Efficient of Friction (µ) |
|---|---|---|---|---|
| 1 | 1.4147 | 628.31 | 35.1 | 0.541 |
| 2 | 1.4147 | 837.75 | 35.3 | 0.497 |
| 3 | 1.4147 | 1047.19 | 36.3 | 0.448 |

**Table 15: Wear Test Values of Aluminum Pin on Steel Disk at a Constant Contact Pressure**

| S. No | Contact Pressure (MPa) | Rubbing Velocity (mm/sec) | Contact Temperature ($^{O}$c) | Wear (µm) |
|---|---|---|---|---|
| 1 | 1.4147 | 628.31 | 35.1 | 7 |
| 2 | 1.4147 | 837.75 | 35.3 | 14 |
| 3 | 1.4147 | 1047.19 | 36.3 | 50 |

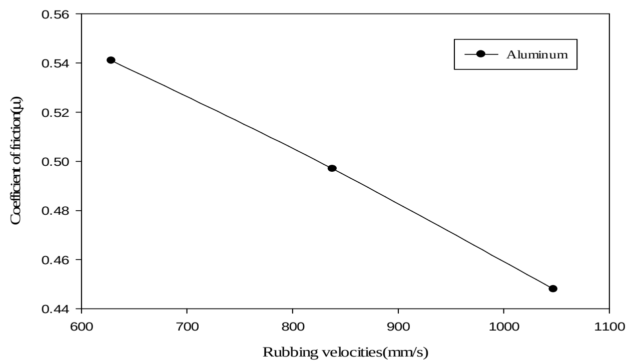


**Figure 8**: **Coefficient of Friction at Constant Pressure for Aluminum Pin**

A Coefficient of friction is obtained for 3mm diameter of the brass pin and steel disc at constant contact pressure in the dry sliding test condition. From the Table 16 it is observed that the coefficient of friction is decreases with increase of load. The increase of contact temperature may be possible reason for decreasing of the coefficient of friction. Wear is obtained for 3mm diameter of brass pin and steel disc at constant contact pressure in the dry sliding test condition. From table 16 it observed that the coefficient friction is decreases with increases of rubbing velocity at constant rubbing velocity. From the Table 16, it is also observed coefficient of friction decreases with the increases of contact temperature. From the Table 17, various rubbing velocity wear is increasing due to the effect of increasing contact temperature. Figure 9, shows the coefficient of friction at constant rubbing velocity for the brass pin.

**Table 16**: **Coefficient of Friction Test Values of Brass Pin on Steel Disk at a Constant Rubbing Velocity**

| S. No | Contact Pressure (MPa) | Rubbing Velocity (mm/s) | Contact Temperature ($^{O}$c) | Co-Efficient of Friction (µ) |
|---|---|---|---|---|
| 1 | 0.7074 | 837.75 | 35.1 | 0.278 |
| 2 | 1.4147 | 837.75 | 37.1 | 0.227 |
| 3 | 2.1220 | 837.75 | 37.6 | 0.096 |

**Table 17**: **Wear Test Values of Brass Pin on Steel Disk at a Constant Rubbing Velocity**

| S. No | Contact Pressure (MPa) | Rubbing Velocity (mm/sec) | Contact Temperature ($^{O}$c) | Wear (µm) |
|---|---|---|---|---|
| 1 | 0.704 | 837.75 | 35.1 | 108 |
| 2 | 1.414 | 837.75 | 37.1 | 69.5 |
| 3 | 2.122 | 837.75 | 37.6 | 77 |

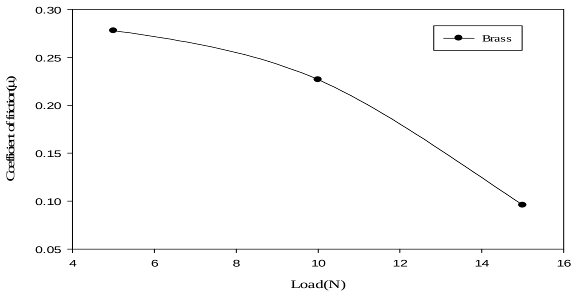


**Figure 9**: **Coefficient of Friction at Constant Rubbing Velocity for Brass Pin**

The Coefficient of Friction is obtained for 3mm diameter of aluminum Pin and Steel disc at constant contact pressure in the dry sliding test condition. From the Table 18, it is observed that the coefficient of friction is decreases with the increase of rubbing velocity. The increase of contact temperature may be possible reason for decreasing of coefficient of friction. Wear is obtained for 3mm diameter of Steel Pin and Steel disc at constant contact pressure in dry sliding test condition. From the below Table 18, constant normal loads are acting on the3mm diameter pin with different rubbing velocities, coefficient of friction decreases due to the effect of contact temperature increases. From Table 18, it observed that coefficient friction is decreases with increases of rubbing velocity at constant load. From the Table 19, it is also observed wear decreases with the increases of contact temperature. Figure.9 shows the coefficient of friction at a constant contact pressure for brass pin.

**Table 18**: **Coefficient of Friction Test Values of Brass Pin On Steel Disk at Constant Contact Pressure**

| S. No | Contact Pressure (MPa) | Rubbing Velocity (mm/s) | Contact Temperature ($^{O}$c) | Co-Efficient of Friction (µ) |
|---|---|---|---|---|
| 1 | 1.4147 | 628.31 | 36.5 | 0.227 |
| 2 | 1.4147 | 837.75 | 36.7 | 0.213 |
| 3 | 1.4147 | 1047.19 | 36.9 | 0.204 |

**Table 19**: **Wear Test Values of Brass Pin on Steel Disk at Constant Contact Pressure**

| S. No | Contact Pressure (MPa) | Rubbing Velocity (mm/sec) | Contact Temperature ($^{O}$c) | Wear (µm) |
|---|---|---|---|---|
| 1 | 1.4147 | 628.31 | 36.5 | 34.5 |
| 2 | 1.4147 | 837.75 | 36.7 | 53.5 |
| 3 | 1.4147 | 1047.19 | 36.9 | 43.7 |

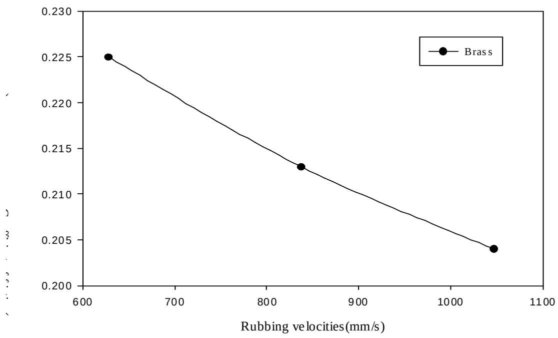


**Figure 10: Coefficient of Friction at Constant Contact Pressure for Brass Pin**

## REGRESSION EQUATION

Regression equation is developed for 3mm diameter Steel Pin for input parameters are contact pressure & Rubbing velocity and output parameter is the coefficient of friction. A proportion of variance value is obtained for equation (1) is 96.99%. Table 20 shows the regression equation variables for steel pin,

$$Y = a + b * \ln(x_1) + \frac{c}{x_2} + \frac{d}{x_2^{\ 2}} + \frac{e}{x_2^{\ 3}} \qquad (1)$$

Where,

X1= Contact Pressure

X2=Rubbing Velocities

**Table 20: Regression Equation Variables for Steel Pin**

| Variable | Value |
|---|---|
| a | -0.482 |
| b | -4.412 |
| c | 5401.855 |
| d | -10221391.931 |
| e | 6324665542.551 |

Regression equation results for 3mm diameter of steel pin are validated from the test conditions at contact Pressure 9 MPa and Rubbing velocity 1500 mm/s. The coefficient of friction from the regression equation corresponding above test condition is 0.40671 as shown in Figure11. It is close to the experimental results; hence the regression equation is validated.

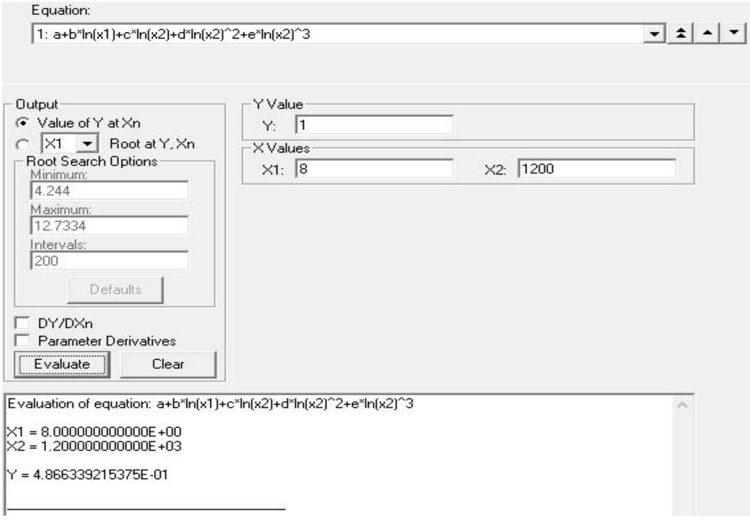


**Figure 11**: **3mm Diameter Steel Pin Regression Equation Result Validation**

X1=8.000000000000E+00

X2=1.200000000000E+03

Regression equation developed for 3mm diameter Aluminium Pin for input parameters are Contact Pressure & Rubbing velocity and output parameter is Coefficient of friction. A proportion of variance value is obtained for equation (2) is 92.99%. Table 21 shows the regression equation variables for the aluminum pin.

$$Y = a + b * x_1 + c * x_1^{\,2} + d * \ln(x_2) + e * \ln(x_2)^2 \qquad (2)$$

**Table 21**: **Regression Equation Variables for Aluminum Pin**

| Variable | Value |
|---|---|
| a | 19.46 |
| b | -7.28 |
| c | -5.39 |
| d | -5.42 |
| e | 0.39 |

Regression equation results for 3mm diameter of aluminum pin are validated from the test conditions at contact Pressure 1 MPa and Rubbing velocity 800 mm/s. The coefficient of friction from the regression equation corresponding above test condition is 0.532 as shown in Figure 12. It is close to the experimental results; hence the regression equation is validated.

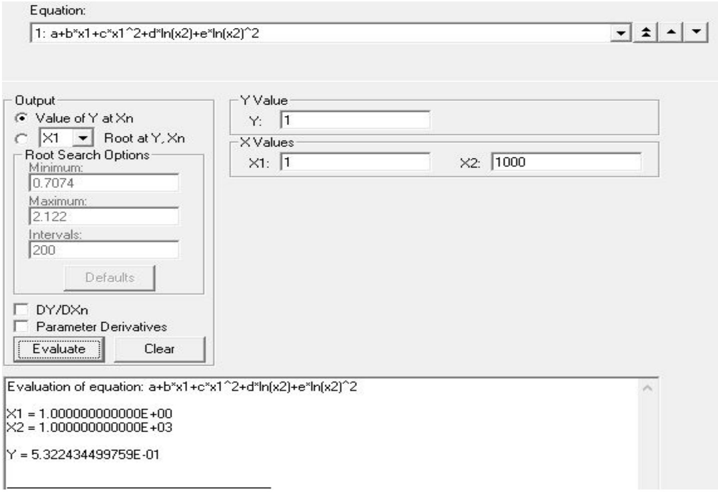


**Figure 12**: **3mm Diameter Aluminium Pin Regression Equation Result Validation**

X1=1.000000000000E+00

X2=1.000000000000E+03

3mm diameter of Brass Pin to develop Regression equation on input parameters are Contact Pressure & Rubbing velocity and output parameter is the Coefficient of friction. A proportion of variance value is obtained for equation (3) is 97.99%. Table 22 shows the regression equation variables results for a brass pin.

$$Y = a + b * x_1 + c * x_1^{2} + d * x_2 + e * x_2^{2} \tag{3}$$

**Table 22**: **Regression Equation Variables for Brass Pin**

| Variable | Value |
|---|---|
| a | 0.22 |
| b | 5.79 |
| c | -6.59 |
| d | -1.59 |
| e | -1.25 |

Regression equation results for 3mm diameter of aluminum pin are validated from the test conditions at contact Pressure 1 MPa and Rubbing velocity 800 mm/s. The coefficient of friction from the regression equation corresponding above test condition is 0.282 as shown in Figure 13. It is close to the experimental results; hence the regression equation is validated.

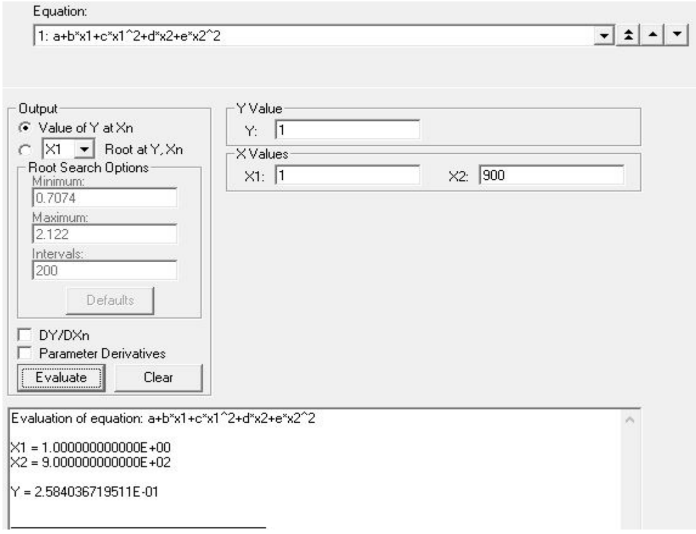


**Figure 13**: **3mm Diameter Brass Pin Regression Equation Result Validation**

X1=1.000000000000E+00

X2=9.000000000000E+02

## CONCLUSIONS

From this study, the results are summarized as: The coefficient of friction decreases with the increase of load for steel-steel, Aluminum-steel and Brass-steel pairs. From the results, it is observed that the steel wear rate is comparatively higher than brass and aluminum. The fluctuations in the graphs of coefficient friction of brass are less when compared to steel and aluminum. Brass shows the least coefficient of friction and Aluminum shows the highest. Brass shows the high wear rate when compared with steel and aluminum for same test conditions. Regression equations are developed for steel on steel, brass on steel and aluminum on steel. The results of coefficient friction obtained from regression equation are close to the experimental results.

### *REFERENCES*

1. *Siddhartha Prabhakar. N, Radhika. N, Raghu. R "Analysis of tribological behavior of aluminum/B4Ccompositeunder dry sliding motion", Procedia Engineering, 2014, Vol. 97, pp994 – 1003.*

2. *HimanshuKala, K. K. S. Mer, Sandeep Kumar "A Review on Mechanical and Tribological Behaviors of Stir Cast Aluminum Matrix Composites", Procedia Materials Science, 2014, Vol. 6 pp 1951 – 1960.*

3. *M. A. Chowdhury, D. M. Nuruzzaman, Mia, M. L. Rahaman "Friction Coefficient of Different Material Pairs Under Different Normal Loads and Sliding Velocities" Tribology in industry ,2012, Vol.34, pp18-23.*

4. *D. M. Nuruzzaman, M. A. Chowdhury, Mia, M. L. Rahaman "Experimental Investigation on Friction and Wear Properties of Different steel Materials", Tribology in industry 2013, Vol.1, pp 42-50.*

5. *Bernard, Mushirabwoba, et al. "Preliminary Study Of Frictional Power Losses In Spur Geared Transmissions." International Journal 7.4 (2017): 199-208.*

6. *Mr. Kiran Deore, Ms. Lalita Aage, Prof. Manoj Hajare "Testing of Wear Rate Frictional Force and Coefficient of Friction Computationally Using Pin On Disk" International Journal of Engineering Trends and Technology (IJETT) 2015, Vol.20, pp 256-259.*
7. *S. Vishnu priya, Arun Prakash. J, Vishnu. V, Christin Gnana Divahar. J "Wear Behavior of Al-8011 and Al-Ni-SiC Metal Matrix Composites" International Journal Of Applied Engineering Research,2015, Vol.10, pp 5858-5862.*
8. *SRIVASTAVA, S. MOHAN "Study of Wear and Friction of Al-Fe Metal Matrix Composite Produced by Liquid Metallurgical Method" Tribology in industry, 2011, Volume 33, pp128-137.*
9. *Ashok Kr. Mishra, Rakesh Sheokand, Dr. R K Srivastava " Tribological Behaviour of Al-6061 / SiC Metal Matrix Composite by Taguchi's Techniques", International Journal of Scientific and Research Publications, 2012, Vol.2, pp1-8.*